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Analysis

Competitive Bioeconomy? Comparing Bio-based and Non-bio-based Primary Sectors of the World

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ABSTRACT

Bioeconomy as a political-economic concept proposes the replacement of fossil resources by bio-based resources in order to address climate change mitigation and counteract resource depletion. The aim of this paper is to figure out how competitiveness across primary sectors, i.e. sector A, bio-based *agriculture*, *forestry and fishing*, and sector B, non-bio-based *mining and quarrying*, is distributed across geographical regions and how it changes over time.

A *constant market share* analysis based upon sectoral output data (2000–2014) shows that competition for market share was significantly lower in sector A than in sector B across 43 countries and one rest of the world country group (ROW), consisting mainly of smaller non-European economies. As a long-term trend, ROW gained market share in both sectors but with a much higher magnitude in sector B, from Europe, the USA, China and other countries. At times when *world growth* was negative or near zero (2009 and around 2013), ROW substantially lost market share in sector B with respect to the other regions mentioned.

1. Introduction

The terms *bioeconomy* and *bio-based economy* refer to one of the recently most prominent political-economic concepts in Europe, and designate the substitution of bio-based resources for fossil resources (e.g. Staffas et al., 2013; Aguilar et al., 2017). The concept addresses ecological objectives, e.g. climate change mitigation and reduction of environmental impacts (European Commission, 2012). Studies confirm — at least conditionally — that an intensified use of biomass can lead to greenhouse gas emission savings (see for example Börjesson Hagberg et al., 2016; Braun et al., 2016; Kalt et al., 2016; Mihai and Ingrao, 2016; Jasinevičius et al., 2017). Apart from its ecological impact, bioeconomy is also intended to have socioeconomic benefits such as fostering economic competitiveness, meeting rising demand, and counteracting resource depletion (European Commission, 2012).

According to the OECD (2006) the concept of a bioeconomy can be defined as “transforming life science knowledge into new, sustainable, eco-efficient and competitive products”. Innovation thus plays a crucial role when realizing the vision of a bioeconomy. Bioeconomic innovations aim at replacing fossil resources for energy, chemicals and materials with renewable and bio-based feedstocks. Looking at related innovation systems, recent studies have identified (e.g. Wield, 2013; Giurca and Späth, 2017) a number of internal and external system weaknesses (e.g., fragmented policies, underdeveloped market formation). There is thus a clear need for policy integration and coordination in order to increase the competitiveness of future bioeconomies. The respective economic competitiveness of fossil and bio-based resources is a decisive factor in ascertaining how far and quickly a transition to a bioeconomy is possible. “Growing demand for feedstocks based on agricultural, silvicultural, and marine sources will increasingly shift global value chains from fossil-rich to biomass-rich countries, but how quickly this will happen depends very much on the cost-competitiveness of the various biomass-based versus fossil-based raw materials” (Kircher, 2014, p. 11; see also Meester et al., 2011 and Purkus et al., 2017).

Although this study focuses on the driving and limiting factors behind a bioeconomic transition, it is vital to realise that a bioeconomic transition will undoubtedly lead to a reallocation of ecological, economic, and social benefits and burdens. This has led some authors to criticize bioeconomic concepts for promulgating a relatively narrow view of sustainability, i.e. one which usually excludes the social dimension (Pülzl et al., 2014, Schmidt et al., 2012, or for an overview, see Priefer et al., 2017). Thus, the possible consequences of large-scale process implementations need to be closely monitored, e.g. the impact on indigenous small farms and forest landowners (Müller and Knierim, 2012). There are, however, concepts such as community forestry and agro-forestry, which attempt to widen the perspective by actively integrating local smallholders and thus contribute to a more inclusive

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bioeconomy (Pfau et al., 2014, Siegner et al., 2017). As a further outcome of bioeconomic transition, the associated redirection of money flows will also affect the economic welfare of those countries that rely heavily on exports of fossil-based commodities. As far as we know, this topic has not been tackled in current bioeconomy-related literature.

In order to gain a comprehensive picture of the global status of bioeconomies in recent years, the aim of this paper is to figure out how economic competitiveness for both bio-based and non-bio-based primary sectors has been distributed across geographical regions and how the pattern has changed over time. The primary sectors mark the very first stages of each global value chain involving primary raw material transformation and therefore mark the boundaries between socioeconomic systems and the environment. Each piece of material that passes through the economic lifecycle (except water and air [Eurostat, 2013]), has at some time been an output of such a sector. Consequently, material-related changes in the entire socioeconomic system are reflected in primary sector outputs and may thus influence their competitiveness. Although several studies dealing with international competition between different commodities already exist (see Materials and Methods), little attention has yet been paid to the issue in terms of raw material type as a main differentiation criterion. To address this research gap we conducted *constant market share* analyses (CMS) in order to derive some insight concerning possible future transitions towards a bioeconomy.

A variety of "international competitiveness" indicators can be found in the literature. Some of them concentrate on location-based issues, such as institutions, infrastructure, education, market efficiency, innovation (Schwab, 2016), fiscal policy, societal frameworks, attitudes and values, science and environment (IMD, 2016), or productivity, spatial issues, qualification of employees and leadership (Porter, 1999). The above indicator class has been described as *determinant-oriented*. A second class of indicators also exists, which is referred to as *result-oriented* (Gries and Hentschel, 1994). This latter class focuses on issues such as country export opportunities, e.g. *revealed comparative advantage*, *terms of trade* or *constant market share* (Milana, 1988; Kemfert, 2002; Ahmadi-Esfahani, 2006; Tilton, 2013; Sujová and Hlaváčková, 2015; French, 2017; Norton, 2017). Determinant-oriented indicators are believed to represent variables causally affecting international competitiveness and, accordingly, to possess forecasting capability. However, a recent study (114 countries, 2006–2014) on the interrelations between determinant-oriented competitiveness and (result-oriented) GDP growth found a strong unidirectional *Granger causality* of GDP growth on competitiveness (Kordalska and Olczyk, 2015). In other words, the determinant-oriented indicator — to which forecasting capability is attributed — is found to be unable to predict economic growth, whereas the latter predicted the former quite well. One could thus conclude that determinant-oriented indicators are not necessarily better per se. Furthermore, as determinant-oriented indicators are usually of a macroeconomic nature they may not be able to differentiate between economic sectors.

As they are intended to measure "international trade competitiveness", conventional applications of CMS only consider export trade flows and completely ignore domestic final consumption and domestic intra- and inter-industry trade. The world trade share — on which CMS analysis is usually based — is thus found to be characterized as a *non-comprehensive* indicator in the literature (Gries and Hentschel, 1994). Irrespective of whether such non-comprehensiveness is regarded merely as a specific feature of the method or as a real disadvantage, it does conflict with the purpose of the present study since the focus here is on primary sectors, and these sometimes show very low export ratios. *Forestry and logging* in Finland (2014), for example, directed only 2% of its output (in monetary terms) towards foreign markets, whereas the remaining 98% went to processing in domestic industries, final consumption and stocks (own calculations based on Timmer et al., 2015). As the figure is also below the 10% level for many other European countries as well (Austria, Cyprus, Denmark, France, UK, Greece, Italy, Portugal, Romania and Sweden), it seems only logical to suggest that domestic flows also be taken into account. If this is not done, the estimation of sectoral competitiveness is based on a relatively small share of exported products, which may lead to wrong conclusions. To overcome this problem, the present study uses data from input-output tables, and thus includes information on both international and intranational trade.

2. Materials and Methods

2.1. Data

In order to employ a more comprehensive world market share indicator this study uses data from input-output tables provided by the *World Input-Output Database* (WIOD) (Timmer et al., 2015). WIOD data has already been used for decomposition analyses in conjunction with other research questions and methods (e.g. Pothen and Schymura, 2015; Pothen, 2017). The 2016 release is structured according to the *International Standard Industrial Classification of All Economic Activities* (ISIC) Rev. 4 and covers the period from 2000 to 2014. The dataset represents trade flows between 56 sectors and five final-use categories for each of 43 countries, and for one rest of the world country group (ROW). For a detailed description of the WIOD data, construction procedures, and underlying assumptions, see also Timmer et al. (2015) and Dietzenbacher et al. (2013). Regarding specific remarks on the 2016 release see Timmer et al. (2016).

For the purposes of the present study, one of the most important statistics is *total output at basic prices* (henceforth simply *output*). This represents the sector-specific sum of all foreign and domestic supplies of that sector. The output of *mining and quarrying*, for example, encompasses export flows as well as deliveries to itself, to the other domestic sectors, to domestic final consumption and to domestic stocks in monetary units. *Basic prices* exclude taxes and transport charges but include subsidies (see OECD Statistics, n.d). The present study focuses on material extraction, i.e. the primary sectors, which are represented by ISIC sections A and B. Section A is related to bio-based industries (see Ronzon et al., 2017) exploiting bio-based resources and covers activities such as *crop and animal production*, *hunting and related service activities* (A01), *forestry and logging* (A02), and *fishing and aquaculture* (A03). Section B denotes non-bio-based industries, which extract fossil resources, and includes *mining of coal and lignite* (B05), *extraction of crude petroleum and natural gas* (B06), *mining of metal ores* (B07), *other mining and quarrying* (B08) and *mining support services activities* (A09) (see United Nations Statistics Division, n.d). Divisions A01, A02 and A03 were first analyzed individually but then aggregated for presentation purposes. Since WIOD does not distinguish between the different divisions of section B, this section was analyzed as a whole. Table 1 shows the framework used in the present CMS analysis and provides sectoral outputs for 2014 on a global level. It is important to note that this analysis follows a production-based approach, assigning the use of natural resources to the country where extraction took place. In contrast, a consumption-based approach would allocate the use to the country where final consumption came about (on this difference see

Table 1
Sectoral framework used for CMS analysis. Global total output at basic prices for 2014 in 10^9 nominal USD based on data taken from the WIOD database (Timmer et al., 2015).

ISIC Rev. 4 primary sectors		Raw material type	Global total output
A	Agriculture, forestry and fishing	Bio-based	5708
A01	Crop and animal production, hunting and related service activities	Bio-based	4911
A02	Forestry and logging	Bio-based	370
A03	Fishing and aquaculture	Bio-based	427
B	Mining and quarrying	Non-bio-based	5963

e.g. Eisenmenger et al., 2016 and Wiedmann et al., 2015). Input-output data are suitable for both approaches.

2.2. Method

A *constant market share* analysis (CMS) was applied here in order to estimate the competitiveness of the aforementioned sectors. CMS decomposes growth during any period into the following four effects: the *world growth effect*, the *commodity-composition effect*, the *market-distribution effect* and the *competitiveness effect*. The rationale behind the method is as follows. A country's exports of a given commodity are expected to grow at a constant market share. This expected export growth is represented by the first three effects, which together, form the structural component of export growth. The difference between expected and actual export growth is assumed to indicate the competitive advantage or disadvantage of the country regarding the commodity in question and is thus called *competitiveness effect* (Milana, 1988). If this is positive, the country has gained market share, and if the value is negative, it has lost market share. The *competitiveness effect* is identical to the non-structural component of export growth. Leamer and Stern (1970) illustrated the interpretation of some CMS effects as follows, where (1) refers to *commodity-composition*, (2) to *market-distribution* and (3) to *competitiveness effects*. "A country's exports may fail to grow as rapidly as the world average for three reasons: (1) Exports may be concentrated in commodities for which demand is growing relatively slowly; (2) exports may be going primarily to relatively stagnant regions; or (3) the country in question may have been unable or unwilling to compete effectively with other sources of supply" (Leamer and Stern, 1970, p. 171).

Additive output changes within a time interval (e.g. single year) are equal to the sum of all effects of that period, suggesting that *world growth effects*, *market-distribution effects* and *competitiveness effects* additively determine the level of outputs. Thus, each one of the effects can have a weaker or stronger, a positive or negative influence on the developmental path of a country's outputs. From that perspective, an effect value near zero indicates low effect importance over outputs, whereas values more distant from zero signify higher effect importance. The importance of effects with regard to the determination of outputs can also be expressed relatively, e.g. as relative importance of *competitiveness effects* with respect to *market-distribution effects* (see Eq. (2)). Theoretically, if the world market increases under the constant market share assumption, positive *world growth effects* will occur for each country while the other effects will be zero.

Most of the recent applications of CMS focused on a selected commodity group such as wood, fruits and vegetables, fish, olive oil or spices. While none of them explicitly considered primary raw materials, in a few cases, all exports were taken into account. Geographically, emphasis has been on rather large economies such as the USA, China, Japan, India, Brazil and Germany. Only two articles were found which provided annual time series of CMS effects (Finicelli et al., 2011; Pavličková, 2013). The majority of studies took no more than four time periods of several years into account (Dieter and Englert, 2007; Kumar and Muraleedharan, 2007; Batista, 2008; Dieter and Englert, 2009; Mulazzani and Malorgio, 2009; Türkekul et al., 2010; Singh and Dey, 2011; Camanzi et al., 2012; Husted and Nishioka, 2013; de Oliveira et al., 2013; Jenkins, 2014; Njiraini et al., 2015; Sekakela, 2016; Shang et al., 2016; Suhana et al., 2016; Wu et al., 2016). The average length of the overall investigation period was ten years.

For the present analysis, and to reveal temporal fluctuations, CMS effects were evaluated annually for the entire period covered by WIOD data (2000–2014). In the calculations, all 43 WIOD countries plus ROW were included separately, while most of the results are presented at an aggregated level. In order to account for exchange rate influences, each analysis was performed twice, once with input-output data as it is (nominal US dollars), and once with data converted to nominal euros using the same exchange rates as applied in the course of database establishment for conversion from local currency to US dollars (published on the WIOD project website). As demonstrated in Dieter and Englert (2009), an individual CMS analysis for each sector A01, A02, A03 and B (or the commodities they produced respectively) was carried out. In contrast to the usual "multi-commodity" approach, each sector thus obtained its distinct CMS effect figures allowing for cross-sectoral comparisons. As a consequence of this procedure, commodity-composition effects always equal zero, which reduces CMS decomposition to three effects. The sum of all sectors' *world growth effects* in the "single-commodity" approach equals the sum of all sectors' *world growth* plus the sum of all commodity-composition effects in the multi-commodity approach. *Market-distribution* and *competitiveness effects* are the same for both approaches (ibid.).

The CMS formulation applied is based on Milana (1988). According to Dieter and Englert (2007) some studies present more sophisticated CMS formulas, in order to capture additional effects. The authors stated that these extended formulas allow for a deeper analysis of a country's performance in international markets but they are also harder to explain and the nature of the data often limits sophisticated analysis. The present study thus uses an adapted version of the Milana formulation, and deviates from it in two aspects: (1) the commodity-composition effect does not appear in the equation, and (2) the meaning of the variables differs (see Eq. (1)).

$$\underset{output\ \ growth}{\Delta q =} \quad \underset{world\ \ growth\ \ effect}{\frac{1}{2}[s^0 + s^1]\Delta Q} + \underset{market-distribution\ \ effect}{\sum_i \frac{1}{2}[s_i^0 + s_i^1]\Delta Q_i - \frac{1}{2}[s^0 + s^1]\Delta Q} + \underset{competitiveness\ \ effect}{\sum_i \frac{1}{2}[Q_i^0 + Q_i^1]\ \Delta s_i} \tag{1}$$

where
q = output of focus sector (e.g. B) located in a country (usually exports of country of focus);
Q = outputs of corresponding sectors (e.g. B) of all countries (usually world exports);
$s = \frac{q}{Q}$ = output share of sector (usually export share of country);
i = index denoting purchasing sector or purchasing final-use category respectively (usually denoting importing country);
Δ = difference between respective term's values at end and at start time of focus period; and superscripts indicate start (0) and end time (1) of focus period.

The higher the share of a region in the world market, the lower is the relative importance of *market-distribution* and *competitiveness effects* on output growth. If, as a hypothetical example, the region of focus were the entire world, the *world growth effect* would fully cover output growth, whereas all other effects would equal zero. Consequently, countries with a higher proportion in the world market show a lower relative importance of *market-distribution* and *competitiveness effects* due to the calculation specified by the CMS approach. One should thus be cautious when comparing the CMS effects of countries with different world market shares. The same applies to the comparison of CMS effects for different sectors, even if they belong to the same country, since each sector's world market is of a different size. Accordingly, in order to assess the relative importance of *competitiveness effects* in a country's sector, the present study uses *market-distribution effects* as comparison values, thus eliminating size effects (see Eq. (2)).

$$I = \frac{|c|}{|c| + |m|} \tag{2}$$

where
I = relative importance of *competitiveness effects* against *market-distribution effect*;
c = *competitiveness effects*;
m = *market-distribution effect*.

Table 2
Geographic aggregation framework used for result presentation in this article.

Country or country group		Countries included
A < B	Countries, where outputs in *mining and quarrying* (B) were higher than in the biomass extracting sectors (A) (2000)	Australia, Canada, Mexico, Norway, Russia, United Kingdom
Asia	Other countries in Asia	India, Indonesia, Japan, South Korea, Taiwan, Turkey
China	China	China
Europe	Other countries in Europe (EU-28 minus United Kingdom, plus Switzerland)	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland
ROW	Rest of the world (including most of the OPEC member countries)	Brazil plus countries not elsewhere stated (aggregate)
USA	United States of America	United States of America

For presentation purposes, six different countries or country groups including all WIOD countries were selected in such a way that the total outputs of the respective primary sectors share the same order of magnitude across all groups. The resulting geographic aggregation framework is shown in Table 2. It should be noted, that CMS effects were calculated individually for each country and aggregated afterwards.

3. Results

3.1. Total Outputs and CMS Effects

Since outcomes of CMS analysis differ depending on the currency in which trade flows have been evaluated, CMS analyses were conducted in US dollars as well as in euros. The results confirmed that exchange rates strongly influenced the developmental course of outputs. Likewise, they affected the sum of all three CMS effects, as output changes between the current year and the year before are reflected in this sum. *World growth effects* showed considerable differences between the two currency outcomes, whereas *market-distribution* and *competitiveness effects* were — once different scaling is neglected — quite similar and differed only in the long run. *Competitiveness effects* as the principal outcome of CMS analysis are fairly robust against short-term exchange rate influences (for an explanation of this observation, see Section 4). Further results are thus presented in US dollars only (the currency applied in WIOD).

3.1.1. Europe and Asia

Regional *world growth effects* (WGE) exhibit some general similarity since change in global output ΔQ is constant across countries with the country's output share s as the only variable determining WGE. As s cannot be negative, WGE — in contrast to the other effects — share the same sign in any given year in all countries. For this reason, they are discussed here only once, using the example of Europe (Fig. 1, left). Measured in US dollars, WGE were either positive or near zero throughout the entire period in *agriculture, forestry and fishing* (A) and in *mining and quarrying* (B), apart from the year 2009, where WGE were negative in both sectors. In A, and particularly in B, the three years at the end of the period (2012–2014) show exceptionally low, but still positive, WGE. WGE in A and in B were correlated ($r = 0.95$), with two outliers being removed in 2005 and 2007 respectively. In both absolute terms, and as a share of total output change, WGE were lower in A than in B. Outputs, *market-distribution effects* (MDE) and *competitiveness effects* (CPE) differ from region to region and are therefore discussed separately. European output growth shows similar patterns in A and B. In the case of sector A, relatively constant output growth is observable. However, this was interrupted by a phase of stagnating or even decreasing outputs in 2009. MDE were predominantly negative in both sectors, more markedly in and after 2009. Whereas before 2009, MDE in A and B show some similarity in (relative) magnitudes across the years, they differ noticeably afterwards. The results for *competitiveness effects* (CPE) most clearly illustrate the difference between the sectors. In A, CPE were near zero across all years, while CPE in B show a substantial, mostly negative impact on output. In 2009, and particularly in 2013, CPE values in B were highly positive. A *t*-test for independent samples considering the individual countries of the focus region across the entire period confirmed that relative importance of CPE against MDE was clearly lower for A ($M = 0.29$, $SD = 0.25$, $N = 392$) than for B ($M = 0.52$, $SD = 0.26$, $N = 392$); $t(782) = -12.64$, $p < 0.001$.

In Asia (Fig. 1, right), output growth of both sectors lasted until 2012 and was only marginally disrupted around 2009. After 2012, output of sector A stagnated, while that of sector B decreased. Compared to Europe, MDE were more often positive in both sectors, but still tended to be negative in the post-2009 phase in A. In B, MDE were mixed without a clear propensity for positive or negative values. In both, the pre- and the post-2009 phase, positive as well as negative MDE occurred with similar frequency and magnitude. As in Europe, CPE were near zero across all years in sector A, whereas CPE in B negatively affected outputs, their being one distinct exception in 2009. The strongly positive CPE of 2013 in sector B in Europe, were absent in Asia. The relative importance of CPE against MDE over the entire period was again clearly lower for A ($M = 0.20$, $SD = 0.20$, $N = 84$) than for B ($M = 0.53$, $SD = 0.25$, $N = 84$); $t(157) = -9.66$, $p < 0.001$.

3.1.2. USA and China

In the USA (Fig. 2, left), output growth was relatively steady and lasted until the end of the period, but was strongly affected by 2009, especially in sector B. In contrast to Europe, Asia and the A < B group, outputs continued to grow after 2009. MDE in both sectors were mostly negative but lost influence after 2009. This pattern is unique inasmuch as MDE in all other regions increased (negatively or positively) in the post-2009 phase (except in sector A of ROW). CPE in A, again, were near zero. As in the case of A < B and China, CPE in B were near zero before 2009 and gained importance afterwards. The relative importance of CPE was only marginally and insignificantly lower for A ($M = 0.30$, $SD = 0.29$, $N = 14$) than for B ($M = 0.36$, $SD = 0.26$, $N = 14$); $t(26) = -0.55$, $p = 0.589$.

China (Fig. 2, right) experienced strong output growth across the entire period in both sectors, this becoming only marginally impaired by 2009. In both sectors and in contrast to all other regions, growth even accelerated after 2009. MDE were, unlike in most other cases, almost completely positive in A as well as in B. MDE in both sectors tended to show increased magnitudes in 2009 and after, at a time when MDE in Europe, Asia and in the A < B group intensified their negative impact on output development. As in all other cases, CPE in A were virtually non-existent during the whole period. In B, a pattern, similar to the A < B group's sector B emerged, with values around zero in the pre-2009 phase and increasing influence in 2009 and after. The relative importance of CPE was clearly lower for A ($M = 0.10$, $SD = 0.10$, $N = 14$) than for B ($M = 0.35$, $SD = 0.32$, $N = 14$); $t(16) = -2.81$, $p = 0.013$.

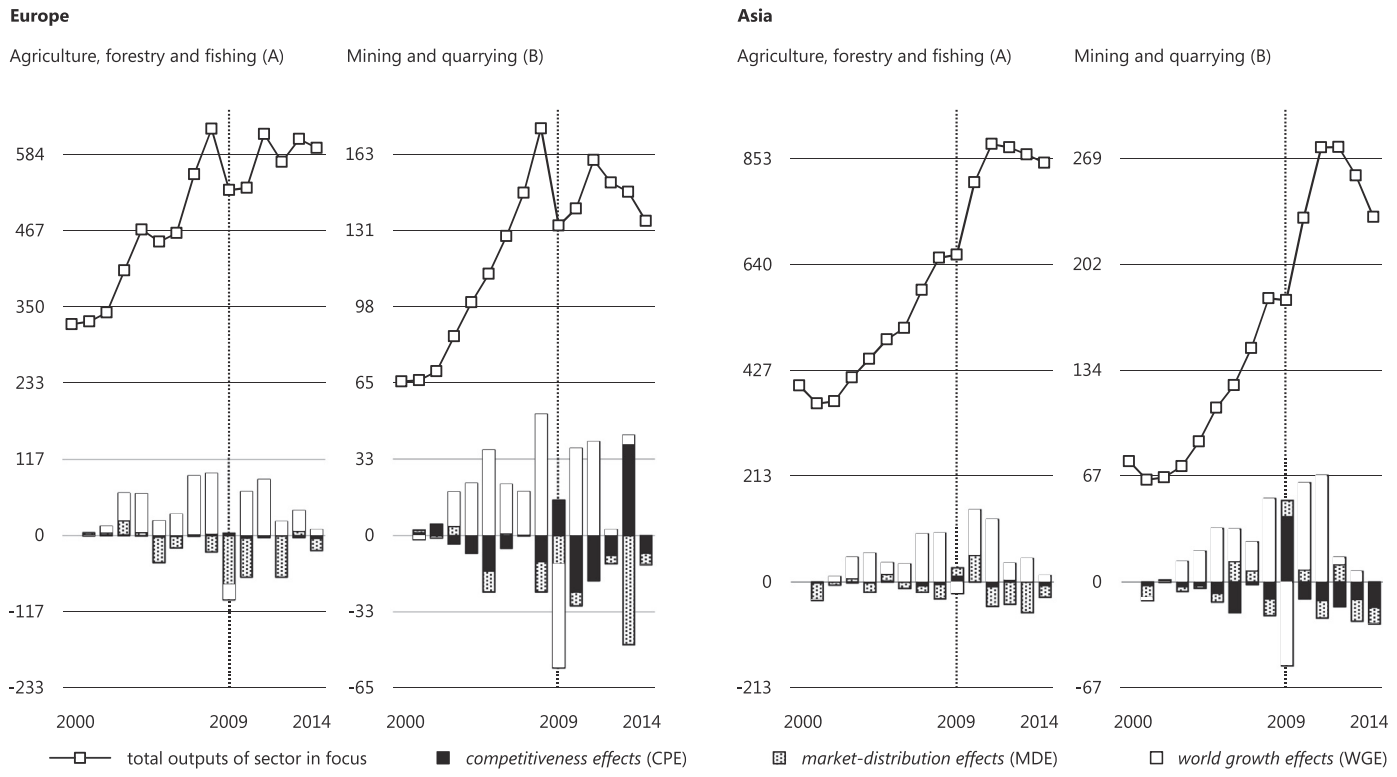

Fig. 1. Total outputs and CMS effects for European (left) and Asian (right) *Agriculture, forestry and fishing* (A) and *Mining and quarrying* (B) sectors (2000–2014) in 10^9 USD (nominal). The line chart represents the total outputs of sectors. Black bars indicate *competitiveness effects*, dotted bars show *market-distribution effects* and white bars stand for *world growth effects*. The sum of all three effects is equal to the change in total outputs between the current year and the year before. The vertical dotted line indicates the year 2009.

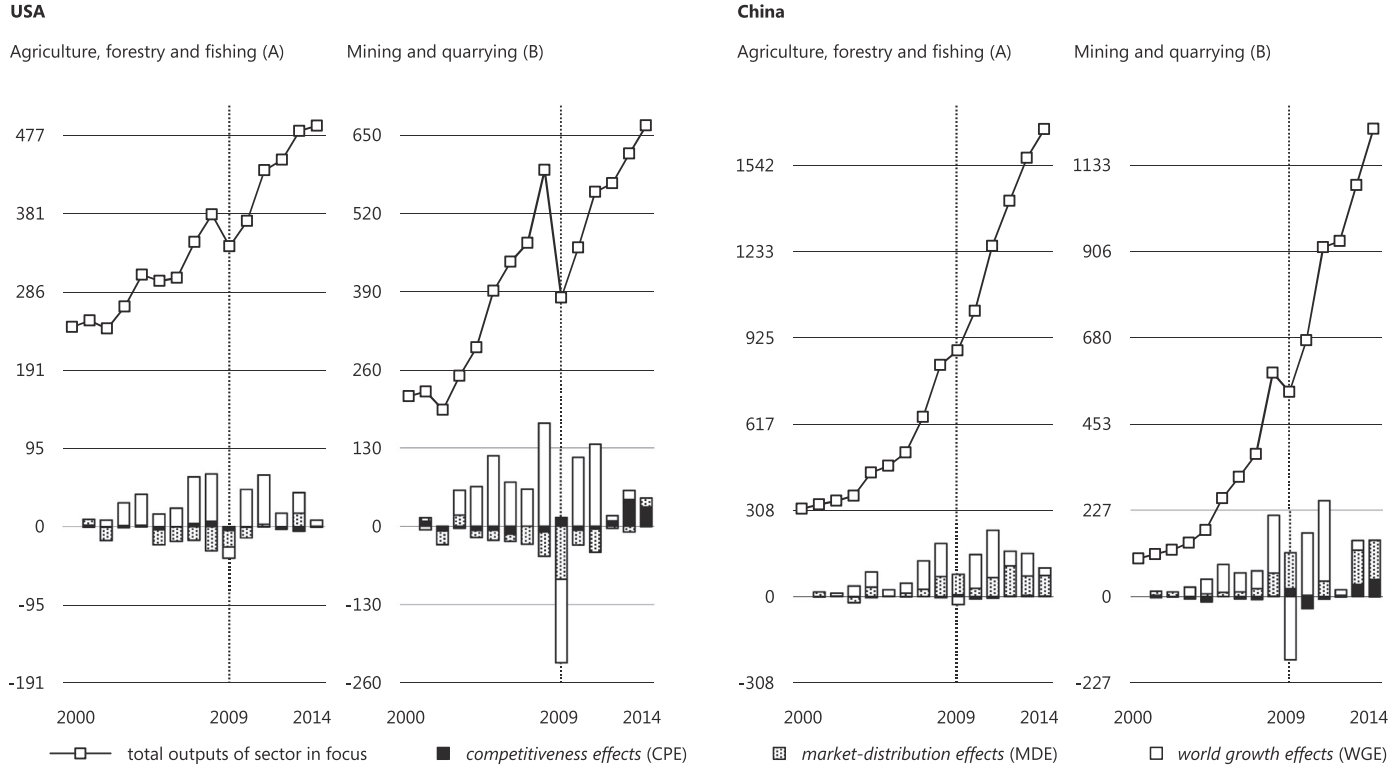

Fig. 2. Total outputs and CMS effects for United States (left) and Chinese (right) *Agriculture, forestry and fishing* (A) and *Mining and quarrying* (B) sectors (2000–2014) in 10^9 USD (nominal). The line chart represents total outputs of sectors. Black bars indicate *competitiveness effects*, dotted bars show *market-distribution effects* and white bars stand for *world growth effects*. The sum of all three effects is equal to the change in total outputs between the current year and the year before. The vertical dotted line indicates the year 2009.

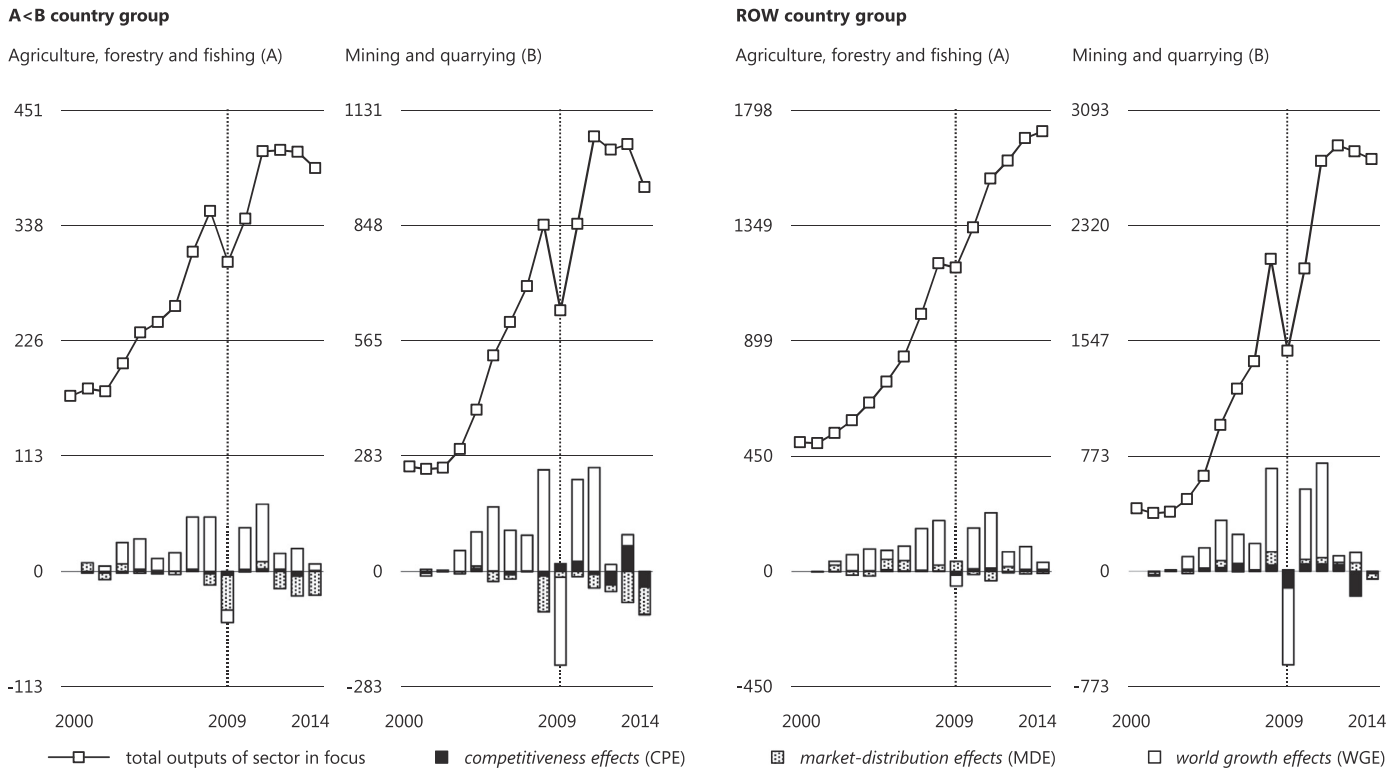

Fig. 3. Total outputs and CMS effects for A < B group's (left) and ROW's (right) *Agriculture, forestry and fishing* (A) and *Mining and quarrying* (B) sectors (2000–2014) in 10^9 USD (nominal). The line chart represents total outputs of sectors. Black bars indicate *competitiveness effects*, dotted bars show *market-distribution effects* and white bars stand for *world growth effects*. The sum of all three effects is equal to the change in total outputs between the current year and the year before. The vertical dotted line indicates the year 2009.

3.1.3. A < B and ROW Country Groups

The A < B country group (Fig. 3, left) shared two characteristics with Europe. Firstly, for both sectors, increasing outputs dropped in 2009 and secondly, stagnated or decreased in and after 2012. MDE were mostly near zero or negative, with increased negative magnitude in and after 2009, which is true for both sectors and in line with most of the other cases. Again, CPE in A were near zero during all years. In contrast to Europe and Asia however, CPE in B were near zero in the pre-2009 phase and mixed afterwards. Hence, CPE influenced outputs of sector B less than in most other regions. This is reflected in the weaker difference between the importance of CPE compared to MDE for A ($M = 0.32$, $SD = 0.27$, $N = 84$) and for B ($M = 0.46$, $SD = 0.26$, $N = 84$); $t(166) = -3.36$, $p = 0.001$.

In the ROW country group (Fig. 3, right), output growth of sector A was relatively steady until the last few years of the period, when a minor slowdown occurred. Output growth in sector B began to stagnate after 2011. The impact of 2009 was low in A but high in B. MDE in A were rather positive in the pre-2009 phase, while for the post-2009 phase, no clear pattern could be identified. In B, MDE were predominantly positive or near zero throughout the entire period. CPE values in A were approximately zero, whereas in B they were largely positive, except for 2009 and 2013. The relative importance of CPE against MDE was clearly lower for A ($M = 0.21$, $SD = 0.22$, $N = 28$) than for B ($M = 0.53$, $SD = 0.27$, $N = 28$); $t(54) = -4.71$, $p < 0.001$.

3.1.4. All Regions

As a rough summary, one can state that MDE of both, sector A and sector B, were rather negative in Europe, the USA and the A < B group, mixed in Asia, and positive in both China and the ROW group. CPE in A were constantly near zero across all regions. In contrast, CPE in B had a considerable influence on output growth in all regions and tended to gain even more importance in the second half of the investigation period. Hence, across all years, the relative importance of CPE compared to MDE was higher in B than in A, notwithstanding the fact that differences between regions were found regarding the intensity of this dissimilarity. Considering the WIOD countries individually (see Table 2), the relative importance of CPE against MDE was significantly lower in sector A ($M = 0.28$, $SD = 0.25$, $N = 616$) than in sector B (0.51, $SD = 0.26$, $N = 616$); $t(1230) = -15.98$, $p < 0.001$. According to Cohen (1992), the resulting effect size ($r = 0.41$) may be rated as being between medium and large. Canada and Norway were the only two countries showing a higher relative importance of CPE in A than in B.

3.2. Cumulative Competitiveness Effects

Fig. 4 shows *competitiveness effects* (CPE) in a cumulative form, starting at zero in the year 2000. This form of presentation displays the regional interplay of CPE gains and losses, as the sum of the CPE over all regions in each year and sector equals zero. In *agriculture, forestry and fishing* (A), CPE were generally low. The most interesting result is the accumulation of CPE in ROW, fed by all other regions. In Europe and the USA, a relatively stagnant development in CPE in A between 2000 and 2009 was followed by a slightly negative trend. China experienced a negative development between 2000 and 2011, but the subsequent period exhibits constant recovery. Asia was exposed to a slightly negative movement over the entire period of analysis, while for the A < B group no clear pattern is visible.

Concerning the interactions between regions in *mining and quarrying* (B), a long-term trend similar to that found in sector A was observable, where ROW gained CPE from all regions, except from the A < B country group. This trend was interrupted by events in 2009 and around 2013. Taking the results on *world growth effects* (WGE) into account suggests that in ROW's sector B positive CPE approximately coincided with positive WGE, while negative CPE coincided with negative WGE (or WGE near zero respectively). The opposite was true for the B-sectors in Europe, the USA and China, which exhibited positive CPE when WGE were low or negative and vice versa. Except for 2013,

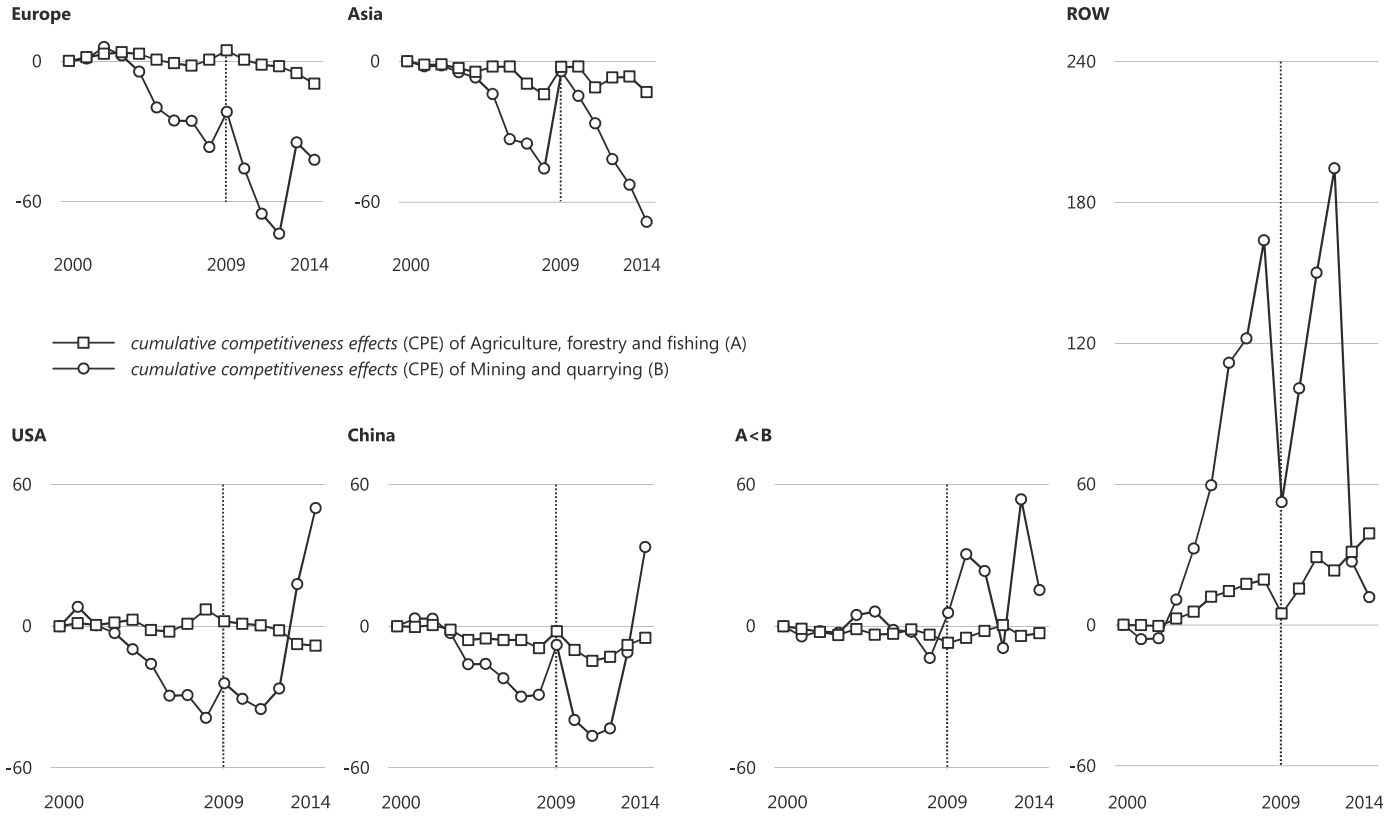

Fig. 4. Cumulative *competitiveness effects* of primary sectors (2000–2014) in 10^9 USD (nominal) by regions. Squares represent *competitiveness effects* of sector A, circles *competitiveness effects* of sector B. The sum over all regions in any year and sector equals zero. Note that effects refer to output changes between the current year and the year before. The vertical dotted line represents the year 2009.

Asia showed the same behavior. The development of CPE in sector B of the A < B group is neither similar to that for ROW nor to that for the other countries or country groups. Both, long-term trend and sudden events led to substantial alterations of *competitiveness effect* distribution across regions.

4. Discussion and Conclusions

As output is a monetary quantity expressed in a specific currency, it must reflect the impact of variations in exchange rates (and variations in purchasing power). CMS decomposition of outputs measured in both US dollars and euros, revealed that most of the resulting differences were offset by world growth effects, whereas the other effects showed quite similar results in both currencies (ignoring different scaling). This observation can be explained by the way the CMS effects are calculated.

While Δs, as the difference between two ratios, is dimensionless and therefore independent of currency, ΔQ is a currency-bound value, representing a combination of non-monetary output level changes, on the one hand, and currency value changes on the other hand. Each CMS effect consists of at least one term including a "mean factor" (e.g. $\frac{1}{2}[s^0 + s^1]$) and a "difference factor" (e.g. ΔQ; see Eq. (1)). Since the summands of the mean factor (e.g. s^0, s^1) cannot be negative the mean factor exhibits a reduced probability for direction changes within time intervals, leading to low volatility and finally to a low determination coefficient regarding the whole CMS effect. As a consequence, CMS effects correlate with the difference factors, i.e. with the (currency-dependent) ΔQ for the *world growth effect*, and the (currency-independent) Δs for the *competitiveness effect*. As the *market-distribution effect* is a difference between two terms — both of them including ΔQ as difference factor — they largely tend to cancel out each other's currency dependency. *Market-distribution effects* and *competitiveness effects* thus can be described as mostly invariant to the impact of changes in exchange rates and purchasing power and thus also to the choice of currency as unit of measurement.

Comparing the development and distribution of competitiveness indicators by means of a CMS analysis for both bio-based (A) and non-bio-based (B) primary sectors the present study identified several notable differences. While *mining and quarrying* has been globally affected by (non-structural) *competitiveness effects*, *agriculture, forestry and fishing* showed stronger dependency on *world growth* and *market-distribution*, which are the structural components of output growth. Compared to the other effects, *competitiveness effects* exerted a negligible influence on outputs from the bio-based primary sector. We thus suppose that competitive advantage plays a minor role in that sector as a result of its low foreign trade involvement.

Generally, a high relative importance of *competitiveness effects* occurs when a subset of countries gains market share at the expense of the remaining countries due to an increase in their outputs, while distributing these additional outputs evenly to the markets (i.e. all markets grow at a similar rate). If the importance of *competitiveness effects* is low, additional outputs are distributed more unevenly while output growth takes place at comparatively constant market shares among all countries. Empirically, the relative importance of *competitiveness effects* compared to *market-distribution* was higher in the non-bio-based primary sector in 41 countries and in the ROW country group. However, this pattern did not show up in the case of Canada and Norway, which appear to be exceptional cases due to their specific characteristics. Canada and Norway are countries with a relatively high *mining and quarrying* output. They present more stable market share in *mining and quarrying* than most of the other countries. Reviewing potential endogenous factors on such market share stability using the PEST or PESTEL framework (e.g. Gupta, 2013, or Sandberg et al., 2016), it was found that these countries exhibit relatively steady political, economic and social conditions, and at the same time are fully developed in terms

of technology and environmental standards. Thus, fundamental changes regarding the competitiveness of these countries are not to be expected.

Extraction of bio-based resources closely follows the combined effects of *world growth* and *market-distribution*. How does this finding fit in with the observation that consumption of biomass is economically inelastic and mainly driven by population growth (Steinberger et al., 2010)? A possible explanation for this pattern can be found by distinguishing between production volume and production value. While overall production of biomass in terms of volume might be relatively stable and inelastic, the related prices may react more strongly to *world growth* and *market-distribution effects*.

Apart from these general patterns in relation to the effects investigated, a long-term trend regarding the redistribution of *competitiveness effects* was also found. In both sectors, ROW increasingly accumulated market share at the expense of most other regions. Additionally, two events included in the observed time period had strong impacts, particularly in sector B. The first event was the economic crisis of 2007/08, whose consequences became visible in the form of negative *world growth effects* in 2009. The second event was a slowdown in *world growth* around 2013, possibly related to the onset of large scale unconventional oil and gas extraction (fracking) in the USA and Canada which resulted in price reductions. Interestingly, both events led to the same changes in the distribution of *competitiveness effects*. While they exerted a negative impact on the ROW country group, they had a positive impact on Europe, the USA and China. The fluctuations in 2009 clearly show that developmental paths of competitiveness, as assessed by means of CMS analysis, are sensitive to global (i.e. exogenous) macroeconomic events.

Increasing demand for outputs from *agriculture, forestry and fishing* generated by growing economies will mainly lead to *domestic* output increases. If the bioeconomy, by definition, equals the economic production of the bio-based primary sector, then expanding bioeconomies are rather to be expected in regions where *market-distribution effects* in that sector are positive (China, ROW). However, this would not necessarily imply a shift in relative output shares of non-bio-based primary sectors towards bio-based primary sectors. Kircher (2014) indicated that the cost-competitiveness of bio-based versus fossil-based material is a key factor in the transition towards a bioeconomy. Thus, given that positive *competitiveness effects* mainly represent cost advantages, it appears that the relation between sectors is likely to be more relevant than absolute values. From such a perspective, and taking the findings of the applied production-based approach into account, occurrences in the *mining and quarrying* sectors seem to be far more important than those in *agriculture, forestry and fishing* when attempting to determine the necessary local or regional conditions for bioeconomic development. However, results in 2009 suggested that positive *competitiveness effects* do more than indicate local endogenous factors such as price or cost advantages, increased delivery reliability or adaptability to customer requirements (Dieter and Englert, 2009) and so forth. They also point to sudden alterations in trade structures as a result of exogenous, global macroeconomic disturbances, which are not necessarily related to changes in relative production costs. Therefore, further research is needed on the relationship between the fluctuating market shares identified in *mining and quarrying* on the one hand, and on changes in the cost structure for bio-based and non-bio-based materials on the other hand. Furthermore, the production-based approach presented here could be complemented by a consumption-based approach using the same database. This would identify country-specific differences in non-structural consumption growth of bio-based and fossil resources, and would reveal, for example, whether, and to what extent, the loss of market share in European non-bio-based sectors coincided with an increased share in biomass consumption.

With regard to a hypothetical transition towards a bioeconomy, we presume that an increased use of biomass for energy and material purposes may at the same time lead to an increase in its income elasticity, assuming transition is understood as a pure substitution of fossils by biomass, and ignoring potential changes in the economic system. In such a scenario the *world growth effects* of bio-based primary sectors are likely to be more intensely related to global macroeconomic developments and to be more highly exposed to competition effects. If this were presently the case, Europe would probably face marked negative effects in its biomass sectors. Additionally, increased income elasticity is associated with the risk of becoming subject to rebound effects and with accelerated output growth due to rising incomes, something which has to be observed very closely. However, as there is still no common understanding of what a bioeconomy really means (Pülzl et al., 2014) there is no reason why other, more radical transition scenarios for the global economic system may not be given due consideration.

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